Earth's bulk structure and heterogeneity from big data and full-spectrum tomography

Reconciliation of diverse techniques and big data across traditionally siloed disciplines has emerged as a frontier area for Earth exploration. Future challenges include: (1) Leveraging both legacy and evolving community expertise towards harnessing the burgeoning geophysical data, and (2) Modeling physical properties in a way that facilitates self-consistent inferences between geodynamics, geochemistry, seismology and mineral physics. We present progress towards a community three-dimensional reference Earth model (REM3D) and demonstrate their utility for robust inferences on interior structure.

Progress in modeling the Earth's interior is driven by diverse data, ranging from astronomic-geodetic constraints to full seismic waveforms and derivative measurements of body waves (~1 – 20s), surface waves (~20 – 300s) and normal modes (~250 – 3000s). Full-spectrum tomography employs these observations to constrain physical properties – seismic velocity, anisotropy, density, attenuation and the topography of discontinuities – in variable resolution. Reconciliation of data from research groups worldwide involves retrieving the missing metadata, archiving in scalable storage formats, documenting outliers indicative of the limitations in some techniques, and quantifying summary reference data with uncertainties.

Robust thermo-chemical inferences on heterogeneity require self-consistent descriptions of bulk properties and lateral variations as constrained by the reference datasets. A new radial reference model (NREM1D) is constructed to account for nonlinear effects due to strong crustal variations and geographic bias in sampling heterogeneities. NREM1D is the first model since PREM to constrain jointly the average elastic properties, density and attenuation and represents more accurately the properties of Earth's bulk constituents.

Tomographic inversions reveal that diverse datasets do not require pervasive radial anisotropy, a proxy for dynamic flow in the mantle, at depths below ~300 km. Joint inversions reveal denser-than-average anomalies ([illegible]1% peak-to-peak) at the base of the mantle roughly coincident with the low-velocity superplumes. The relative variation of shear velocity, density and compressional velocity disfavors a purely thermal contribution to heterogeneity in the lowermost mantle, with implications for the long-term stability and evolution of superplumes.